13	**(a)**		$x = Ut$ $y = Vt - \frac{1}{2}gt^2$	**M1***	**3.3**	Setting up expressions for x and y using $s = ut + \frac{1}{2}at^2$ with $a = 0$ in x and $\pm g$ in y oe. **M0** if using U instead of V vertically	Allow sign errors. May use $t = x / U$ in $y = Vt + \frac{1}{2}at^2$
			$y = V\left(\frac{x}{U}\right) - \frac{1}{2}g\left(\frac{x}{U}\right)^2$	**M1dep***	**3.4**	Eliminating both t terms in y to get an equation in y, x, U, V (and possibly g)	
			$y = \frac{Vx}{U} - \frac{gx^2}{2U^2} \Rightarrow 2U^2y = 2UVx - gx^2$	**A1** **[3]**	**2.2a**	**AG** so sufficient working must be shown	www
13	**(b)**		B passes through $\left(a, \frac{1}{2}a\right) \Rightarrow 2U^2\left(\frac{a}{2}\right) = 2UVa - ga^2$ $\left(\Rightarrow U^2 = 2UV - ga\right)$	**B1**	**3.4**	Substituting $\left(a, \frac{1}{2}a\right)$ into given result from **(a)**	
			B passes through $(4a, 0) \Rightarrow 2UV(4a) - g(4a)^2 = 0$ $\left(\Rightarrow UV - 2ga = 0\right)$	**B1**	**3.1b**	Substituting $(4a, 0)$ into given result from **(a) –** note that using $(3a, 0)$ is not a **MR**	
			$U = \sqrt{3ga}$, $V = \frac{2\sqrt{ga}}{\sqrt{3}}$ or $2U = 3V$	**M1***	**2.1**	Solve simultaneously (oe) to find either U or V (or their squares) in terms of a and g only, or for a linear equation (oe) in V and U only, if correct $2U = 3V$	oe e.g., if correct $V^2 = \frac{4}{3}ga$ and $U^2 = 3ga$
			$\tan\theta = \frac{V}{U} \Rightarrow \tan\theta = \frac{\frac{2}{\sqrt{3}}\left(\sqrt{ga}\right)}{\sqrt{3ga}}$	**M1dep***	**3.1b**	Using $\tan\theta = \frac{V}{U}$ with their U and their V	
			$\tan\theta = \frac{2}{3} \Rightarrow \theta = 33.7°$ (3 sf)	**A1** **[5]**	**2.2a**	awrt 33.7 (an answer of 36.9 from using $(3a, 0)$ scores (if from correct working) **B1 B0 M1 M1 A0**)	

13	**(c)**		$\sqrt{3ga+\frac{4}{3}ga}=54.6$	**M1**	**3.4**	Using $\sqrt{U^2+V^2}=54.6$ to set up an equation in a (and possibly g)	
			$a=70.2$	**A1**	**1.1**	www awrt 70.2	an answer of 97.344 (awrt 97.3) from using $(3a, 0)$ in **(b)** scores **M1 A0**
				[2]			
			Alternative 1				
			$54.6\cos(33.7...)=\sqrt{3ga}$ **or** $54.6\sin(33.7...)=\sqrt{\frac{4}{3}ga}$	**M1**		Setting either the horizontal component equal to their U (from **(b)**) or the vertical component equal to their V (from **(b)**). Allow sin/cos confusion	**M0** for an unsupported value of θ (if used)
			$a=70.2$	**A1**		www awrt 70.2	
				[2]			
			Alternative 2				
			$a=\frac{UV}{2g}=\frac{54.6\cos(33.7...)\times 54.6\sin(33.7...)}{2g}$	**M1**		Using their expression for a (possibly seen in **(b)**) in terms of U and V with 54.6 and their θ. **M0** for an unsupported value of θ	Allow sin/cos confusion
			$a=70.2$	**A1**		www awrt 70.2	
				[2]			

13	**(d)**		$0 = V^2 - 2gH \left(\Rightarrow H = \frac{V^2}{2g} \right)$	**M1***	**3.3**	Setting up the model using $v^2 = u^2 + 2as$ with $v = 0$ and a = - g	H is the maximum height of B
			$H = \frac{1}{2g}\left(\frac{4ga}{3}\right) = \frac{2}{3}a$	**M1dep***	**3.4**	Using their expression for V from **(b)** to get an expression for H in terms of a (oe) e.g., $H = \frac{V^2}{2g}$ where $V = 54.6\sin\theta$ (allow $\cos\theta$) with their value of θ	**M0** for an unsupported value of θ
			$H = \frac{2}{3}(70.2) = 46.8\,(\text{m})$	**A1** **[3]**	**2.2a**	awrt 46.8	an answer of 54.756 (awrt 54.8) from using $(3a, 0)$ in **(b)** scores **M1M1A0**
			Alternative 1				
			$0 = V - gt \Rightarrow t = \frac{54.6\sin(33.7...)}{g}$	**M1***		Find t at maximum height with $v = 0$, a = - g and u = their V ¹ 54.6 (allow sin/cos confusion). **M0** for an unsupported value of θ	$t = 3.090472522\ldots$
			$H = (54.6\sin(33.7...))t - \frac{1}{2}gt^2$ $= (54.6\sin(33.7...))(3.09...) - \frac{1}{2}g(3.09...)^2$	**M1dep***		Substituting their t into $s = Vt - \frac{1}{2}gt^2$	V ¹ 54.6 (allow sin/cos confusion)
			$H = 46.8$ (m)	**A1**		awrt 46.8	
				[3]			
			Alternative 2				
			$x = 2a \Rightarrow 2U^2y = 4UVa - 4ga^2$	**M1***		Setting $x = 2a$ or $1.5a$ and substituting into path equation from **(a)**	
			$2(54.6\cos(33.7))^2 H =$ $4(54.6\cos(33.7))(54.6\sin(33.7))(70.2) - 4g(70.2)^2$	**M1dep***		Substituting their U, V and a to form an equation in H (and possibly g) only. **M0** for an unsupported value of θ	U and V ¹ 54.6 (allow sin/cos confusion)
			$H = 46.8$ (m)	**A1**		awrt 46.8	
				[3]			

13	**(e)**		examples of possible refinements include • taking into account the size of *B* • taking into account that *B* is not a particle • taking into account the spin of *B* • taking into account the dimensions of *B* • taking into account the wind/weather • taking into account the thickness of the wall (which is assumed to be 'thin') • taking into account the clearance of the ball at the top of the wall	**B1** **[1]**	**3.5c**	Allow any correct refinement, including use of a more accurate value of *g* rather than the assumed 9.8 **B0** if referring to • the mass or weight or shape of *B* • the ground is unlikely to be horizontal • modelling the problem as three dimensional rather than two dimensional (unless specific detail given) • air resistance (only) If multiple refinements given, then all must be valid to score **B1**	